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within an extensive forest contains, in summer almost double the proportion of carbonic acid in the air over the open country. On the other hand, forest soil is in summer very much poorer in carbonic acid than the soil of the open fields and the amount in the latter rises with elevation of temperature much more rapidly than does that in the former. The diffusion of carbon in the soil seems to be slow, as its quantity appears to vary greatly in places close to each other.

THE PHYLLOTAXIS OF LEAVES, by A. P. Morgan, M. D.—1. The arrangement of leaves upon the stem is denominated *phyllotaxis*. Leaves are arranged upon the stem in three principal ways; (1) they are *alternate*, (2) they are *opposite*, (3) they are *verticillate* or *whorled*. Leaves are alternate upon the stem when but a single leaf grows at each node. Leaves are opposite when two leaves grow at each node upon opposite sides of the stem. The leaves are verticillate or whorled when more than two leaves grow in a circle or whorl around each node of the stem.

I. *Alternate Leaves*.—2. Alternate leaves are arranged upon the stem in a succession of spiral *cycles*. The length of each cycle is determined by the distance from any one leaf to the leaf directly above it upon the stem. The cycle is represented by a fraction of which the numerator denotes the number of times the spiral winds around the stem, and the denominator indicates the number of leaves in the cycle.

3. The various arrangements of alternate leaves are designated in accordance with the numbers of their vertical ranks upon the stem; these are always the same as the number of leaves in the cycles.

4. It has been ascertained that with rare exceptions the cycles in the various arrangements of alternate leaves are represented by the series of fractions;

1-2, 1 3, 2-5, 3-8, 5-13, 8-21, 13-34, &c.

It is here proposed to amend this series by placing at its beginning 0-1. In this series the numerator of each fraction after the first two is obtained by adding the numerators of the two preceding fractions, and the denominator is obtained by adding their denominators.

5. The series 0-1, 1-2, 1 3, 2-5, &c, represents the different cycles of arrangement when we follow the shortest path around the stem. If we go around in the opposite direction, by the longest route, the series will be, 1-1, 1-2, 2-3, 3-5, 5-8, 8-13, 13-21, 21-34, &c., in which each fraction is the complement of the corresponding fraction in the preceding series.

6. *The 0-1 Cycle.*—The 0 1 cycle applies only to the simplest of Phænogams, such as *Lemna* and *Wolffia*; there is but one leaf and no spiral. It represents the primeval marchantioid frond, the common ancestor of all Monocotyledons. Probably no plant rising to any height has a stem with *monostichous* or one-ranked leaves.

7. *The 1-2 Cycle.*—In the 1-2 cycle the spiral makes one turn and bears two leaves. The 3d leaf stands directly over the 1st, the 4th over the 2d, etc.; the odd numbers being ranged on one side of the stem and the even numbers on the other. The leaves are *distichous* or two-ranked. Each leaf is 1-2 the circumference of the stem or 180 degrees distant from the preceding leaf. Examples of this mode of arrangement are to be found in the alternate leaves of the Elm and of Grasses.

8. *The 1-3 Cycle.*—In the 1-3 cycle there are three leaves on one turn of the spiral. The 4th leaf stands directly above the 1st, the 5th above the 2d, the 6th above the 3d, etc. The leaves are *tristichous* or three-ranked. Each leaf is at a distance from the preceding leaf equal to 1-3 the circumference of the stem or 120 degrees. The Alder and Sedges furnish examples of tristichous leaves.

9. *The 2-5 Cycle.*—The 2-5 cycle is the most common of leaf arrangements, and may be observed in most Exogenous plants, as the Cherry, Poplar, etc. The 6th leaf stands directly over the 1st, but is not reached until the spiral has wound twice about the stem. Hence the leaves are *pentastichous* or five-ranked. The angular divergence of the leaves is 2-5 the circumference of the stem, or 144 degrees.

10. *The Higher Cycles.*—In the 3-8 cycle, the leaves are eight-ranked and the angular divergence is 135 degrees. In the 5-13 cycle the angular divergence of the leaves is 137 degrees plus a fraction. Hence the series 0-1 1-2, 1-3, 2-5, 3-8, 5-13, 8-21, 13-34, &c., being infinite, it constantly approximates to some mean value lying between 1-2 and 1-3; the successive cycles being alternately larger and smaller than the mean value, and the difference of their angular divergences continually growing less and less. No two leaves of a cycle are ever farther apart than one-half the circumference of the stem or nearer together than one-third of its circumference.

11. Hence it is that in the higher cycles it becomes difficult to trace the spiral arrangement of the leaves, and to distinguish their vertical ranks. For example, the difference between the 5-13 and 8-21 arrangement is only 1-273 of the circumference of the stem, the difference between the 8-21 and 13-34 arrangement is 1-714 of the circumference. It is evident that a very slight irregularity of growth

will render the exact order of superposition uncertain. And cases no doubt occur in which each leaf stands alone in its own vertical rank and the arrangement is what is termed *curviserial*. Such a cycle may be marked $\infty-\infty$; the angle of divergence is such that it is not possible to divide the circumference by it, and hence no leaf can be placed exactly above another.

12. Nevertheless, we are enabled to mark the succession of the leaves and thus to determine the order of their arrangement, by means of the *secondary* spirals. In every cycle after the first two, there are one or more orders of parallel secondary spirals. These pursue an oblique direction between the primary generating spiral and the vertical ranks to which it gives rise. If we mark the alternate leaves of any axis in the order of their succession, beginning with the lowest, by the series of natural numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, &c., we may exhibit the primary and secondary spirals and the vertical ranks of the different cycles as follows:

a. The 0-1 cycle. (Fig. 1.) 1 vertical rank, 1, 2, 3, 4, 5, &c.

b. The 1-2 cycle. (Fig. 2.) 1 spiral of the 1st order, 1, 2, 3, 4, 5, &c.; 2 vertical ranks, 1, 3, 5, 7, 9, &c., and 2, 4, 6, 8, 10, &c.

c. The 1-3 cycle. (Fig. 3.) 1 spiral of the 1st order, 1, 2, 3, 4, 5, &c.; 2 spirals of the 2d order, 1, 3, 5, 7, 9, &c., and 2, 4, 6, 8, 10, &c.; 3 vertical ranks, 1, 4, 7, 10, 13, &c., 2, 5, 8, 11, 14, &c., and 3, 6, 9, 12, 15, &c.

d. The 2-5 cycle. (Fig. 4.) 1 spiral of the 1st order, 1, 2, 3, 4, 5, &c.; 2 spirals of the 2d order, 1, 3, 5, 7, 9, &c., and 2, 4, 6, 8, 10, &c.; 3 spirals of the 3d order, 1, 4, 7, 10, 13, &c., 2, 5, 8, 11, 14, &c., and 3, 6, 9, 12, 15, &c.; 5 vertical ranks, 1, 6, 11, 16, 21, &c., 2, 7, 12, 17, 22, &c., 3, 8, 13, 18, 23, &c., 4, 9, 14, 19, 24, &c., and 5, 10, 15, 20, 25, &c.

e. The following table exhibits the successive orders of spirals in each cycle as far as the 13-34 cycle. The signs † and - indicate the direction of the spirals to the right or left of the vertical line, as compared with the direction of the primary generating spiral.

13. From a consideration of the origin and de-

5
4
3
2
1

Fig. 1.

7 6
5 5
3 4
1 2

Fig. 2.

9 10 8
6 7 6
3 4 2
1

Fig. 3.

15 16 14 12
13 11 9 7
10 8 6 4
5 3 1 2

Fig. 4.

TABLE I.

C	I	II	III	IV	V	VI	VII
0-1	0						
1-2	+1						
1-3	+1	-2					
2-5	+1	-2	+3				
3-8	+1	-2	+3	-5			
5-13	+1	-2	+3	-5	+8		
8-21	+1	-2	+3	-5	+8	-13	
13-34	+1	-2	+3	-5	+8	-13	+21

velopment of the spirals in these cycles, we deduce the following two fundamental principles:

I. *Every cycle contains within itself in the form of spirals all the vertical ranks of the preceding cycles.*

II. *The consecutive orders of spirals mount one above another alternately to right and left till finally they reach the vertical ranks.*

14. As consequences of these two principles we may infer as follows:

- The system begins with 0-1.
- Every cycle discloses the preceding cycles of the system.
- The number of spirals in the successive orders is the same as the denominators of the fractions which represent the system.
- The spirals of the 1st, 3d, 5th, &c., orders have the same oblique direction to the right or to the left. The spirals of the 2d, 4th, 6th, &c., orders have the same oblique direction to the left or to the right, cross-wise of the spirals of the odd orders.
- The common difference of the numbers in the series which represent any order of spirals is the same as the number of spirals in the order.—[To be continued.]

HELIOPSIS VS. HELIANTHUS.—Probably there are few botanists, especially of the less experienced ones, who are not deceived, at times, in regard to *Heliopsis lævis*, Pers. Even after studying *Heliopsis* and noting its peculiarities, it is still easy to mistake it. Its external appearance is so similar and yet its structure is so different from any *Helianthus* that we wonder how it was possible to be so completely deceived. Were this the case only with myself, it would be nothing remarkable, but I have heard other and more experienced workers speak of the same trouble. It certainly is very exasperating to take considerable pains to obtain neat specimens, lay them carefully in papers, and then find when you reach home that you have collected *Heliopsis* instead of some new *Helianthus*. The polymorphous nature of this species makes it the more difficult to recognize. In the typical form I have found the stem often glaucous and the leaves nearly smooth. The var. *scabra* has the leaves and often the stem